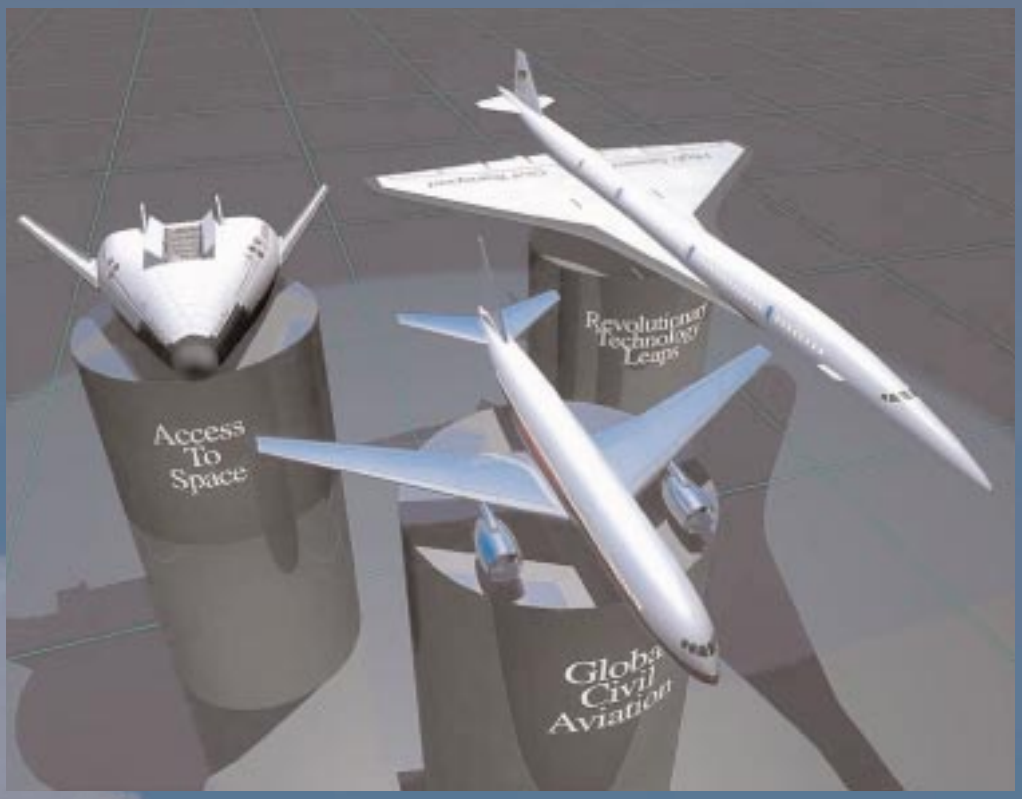
Aeronautics & Space Transportation Technology
Three Pillars for Success

Turning Goals Into Reality



Annual Progress Report 1997-98

NASA

Selected Highlights of Accomplishments

This Annual Progress Report contains the accomplishments made in the past year by the people and partners of NASA's Aeronautics and Space Transportation Technology Enterprise. It is our intent to report annually on the Enterprise's accomplishments toward each goal. In this way the American public may see how their investments in aviation and space technology are working. Below are a few highlights.

Aviation Safety
NASA has developed new anti-icing technologies to make flying safer. A new anti-icing fluid will prevent ice buildup on aircraft awaiting takeoff during winter weather, and an "ice zapper" will keep ice from collecting on aircraft surfaces in flight.

Noise Reduction
Advanced designs for engine fan blades, exhaust nozzles, acoustic liners, and wing flaps have shown a collective 4 decibels of quieting. This should reduce the noisy area surrounding airports by 30 percent.

Aviation System Capacity
NASA and the Federal Aviation Administration developed a series of tools designed to help air traffic controllers and pilots manage aircraft movement in and about airports. These tools, combined, have demonstrated the potential to reduce delays by 20 percent, even in poor visibility.

High-Speed Travel
Eighteen research flights of the Russian Tu-144LL supersonic aircraft were performed. Significant quantities of data were collected to study flight dynamics, cabin noise, and ground effects for landing performance. These data will assist in the design of a U.S. supersonic airliner.

Low-Cost Space Access
The X-33 technology program has completed its critical reviews and begun vehicle assembly. Construction of the launch facility is under way in preparation for the first flight in July 1999.

Message From the Vice President and the NASA Administrator

Leadership in technology-driven innovation fosters the economic strength, social well-being, and national security of the United States. As a Nation, we have seized enormous opportunities and solved difficult problems by using creativity and technological know-how.

Technology is an engine that drives development, and our aerospace industry is a prime technology provider. A foundation of U.S. leadership in aviation and space technology has been our steadfast investment in research.

As we reap the benefits and economic rewards of innovation, we must continue to invest for the future. In 1997, NASA led an effort that defined 10 outcome-oriented "stretch" goals. These goals address our Nation's critical aerospace needs, which include productivity, protecting the environment, low-cost access to space, and most notably, safety, as laid out by the White House Commission on Aviation Safety and Security. These stretch goals are intended to challenge the boundaries of our knowledge and capabilities, and stimulate innovation to sustain U.S. leadership in civil aeronautics and space.

Achieving the stretch goals and capturing future opportunities will require the joint efforts of Government agencies, industry, and academia. Together, this partnership will achieve what no one organization can achieve on its own. "Roadmaps" that show how the programs and interagency activities fit together, are being developed to ensure that the path from today's research into tomorrow's systems is as efficient as possible.

NASA's role is to tackle the long-term, high-risk technology development that can have dramatic transportation benefits for the United States. It is the role of industry, the Federal Aviation Administration (FAA) and others to integrate those technologies into our air and space transportation systems. The working relationship between NASA and the FAA, particularly in aviation safety and air system capacity, is an example of what is needed to achieve our national goals.

Achieving the stretch goals will not be easy. The activities and accomplishments described in this report are investments toward those goals, for the future well-being of our Nation. Whether their benefits are immediate or realized at some future point, each is important. We are proud of the creativity and technical know-how of the men and women performing this work, and we share in their conviction of "turning goals into reality."

Al Gore

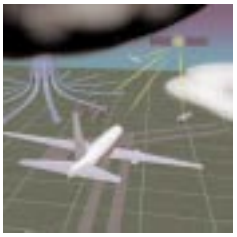
Daniel S. Goldin

Leadership for the 21st Century
In 1995, the Office of Science and Technology Policy published *Goals for a National Partnership in Aeronautics Research and Technology.* This report was a call to reexamine our traditional national partnerships in the context of maintaining leadership in the global aeronautics industry. Three key objectives are cited that define the current and future challenges for leadership:

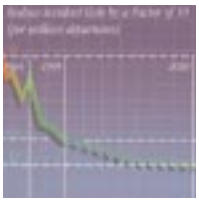
- *Maintain the superiority of U.S. aircraft and engines*
- *Improve the safety, efficiency, and cost-effectiveness of the global air transportation system*
- *Ensure the long-term environmental compatibility of the aviation system*

Many of NASA's programs address the above objectives. However, we felt the objectives were not specific enough to stimulate the progress required. To address this, in 1997, we developed challenging goals to direct our research contributions. We now have 10 outcome-oriented goals as a focus for achievement, in 10- and 25-year time frames.

Our challenge is to ensure the growth and viability of our Nation's air and space transportation systems. The technology pillars and the goals that comprise them are how we plan to tackle these critical needs. The definitions of the Three Pillars and Ten Enabling Technology Goals are presented here, each with a pictorial representation or icon. These icons serve as visual reference points later in this publication.



Pillar 1:
Global Civil Aviation
More than 12,300 commercial airplanes are in service today and air travel will triple in 20 years. Because aviation is critical to our economy and to world trade, our objective is to eliminate barriers to growth.



Goal 1: Aviation Safety
Enabling Technology Goal: Reduce the aircraft accident rate by a factor of five within 10 years, and by a factor of 10 within 25 years.

Goal 2: Emissions Reduction
Enabling Technology Goal: Reduce emissions of future aircraft by a factor of three within 10 years, and by a factor of five within 25 years.

Goal 3: Noise Reduction
Enabling Technology Goal: Reduce the perceived noise levels of future aircraft by a factor two from today's subsonic aircraft within 10 years, and by a factor of four in 25 years.

Goal 4: Aviation System Capacity
Enabling Technology Goal: While maintaining safety, triple the aviation system throughput, in all weather conditions, within 10 years.

Goal 5: Affordable Air Travel
Enabling Technology Goal: Reduce the cost of air travel by 25 percent within 10 years, and by 50 percent within 25 years.

Pillar 2:

Revolutionary Technology Leaps

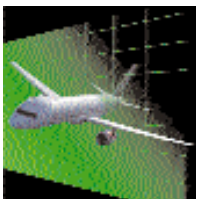
NASA is exploring high-risk technologies that will revolutionize air travel and how aircraft are designed, built, and operated. Creating the next generation of airplanes will greatly benefit the traveling public.

Goal 6: High-Speed Travel

Enabling Technology Goal: Reduce the travel time to the Far East and Europe by 50 percent within 25 years, and do so at today's subsonic ticket prices.

Goal 7: General Aviation

Enabling Technology Goal: Invigorate the general aviation industry, delivering 10,000 aircraft annually within 10 years, and 20,000 aircraft annually within 25 years.



Goal 8: Design Tools and Experimental Aircraft

Enabling Technology Goal: Provide next-generation design tools and experimental aircraft to increase design confidence, and cut the development cycle time for aircraft in half.

Pillar 3:

Advanced Space Transportation

NASA will dramatically decrease the cost of getting to space, while increasing reliability. Achieving these goals will create opportunities for space exploration, science, and commercial ventures for generations.

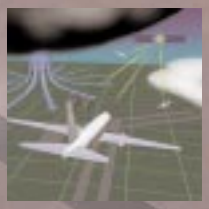
Goal 9: Low-Cost Space Access

Enabling Technology Goal: Reduce the payload cost to low-Earth orbit by an order of magnitude, from $10,000 to $1,000 per pound, within 10 years, and by an additional order of magnitude within 25 years.

Goal 10: In-Space Transportation

Enabling Technology Goal: Reduce the cost of interorbital transfer by an order of magnitude within 15 years, and reduce travel time for planetary missions by a factor of two within 15 years, and by an order of magnitude within 25 years.

Pillar One: Global Civil Aviation



Air travel has become an enormous and critical element of our national economy, providing the backbone for long-distance and global transportation. In 20 years, the projected growth in air travel will almost triple today's volume of operations. Efficient transportation is essential for a growing global economy. It will require our transportation system to provide ever greater reliability, flexibility, and convenience.

As with other forms of transportation, growth in air travel brings issues of congestion, safety, environmental compatibility and ease of access. We have seen new technology open the world of computing and communications in ways we never imagined with a single event, the introduction of the microprocessor. In the same way, the breadth of research in aviation will produce technologies and radical solutions to the challenges facing air transportation.

We have already begun a broad-based and sustained research investment to dramatically improve aviation safety. Together with the FAA, NASA is working on automation tools to improve air traffic safety, efficiency and reliability. We are also jointly developing methods to detect metal fatigue in the aging aircraft fleet, ensuring that older aircraft remain as structurally sound as new ones.

Through the application of advanced technologies and operations research, we will have an air transportation system that will serve our Nation well into the next century.

A pilot evaluates a new simulation of severe weather and other hazardous flight conditions in a NASA research simulator.

NASA's newly commissioned 757 flying laboratory conducts aeronautical research enhancing aviation safety and airspace capacity.

Pillar Two: Revolutionary Technology Leaps

Orville and Wilbur Wright may not have known how their invention would revolutionize the world, but it has. Only 40 years after the first flight, aircraft played a dramatic role in World War II. With the jet engine and many other inventions in aviation, one could not begin to imagine our world today without the power of flight.

The revolution that began in 1903 has taught us that advancements in transportation not only change our mobility, but change our world as well. Like the transcontinental railroad before it, this vast improvement in transportation was dwarfed by the changes that followed in trade and society in general. Revolutionary technologies for transportation will once again push the frontiers of aviation and space for the benefit of our Nation and the world.

Imagine flying to see family, friends, or customers across the Pacific in under 5 hours, instead of today's 10-hour flights! NASA, in partnership with U.S. companies, is working to answer the environmental and economic questions that would make a supersonic aircraft viable, including community acceptance and reasonable ticket prices. Laboratory tests of new engine combustors demonstrated that nitrogen oxide emissions for supersonic flight were reduced to a level only one-fifth of today's jet engines. Methods to quiet these powerful engines are also being developed by NASA scientists and engineers. More research and testing is necessary, but the technology is finally within our sights.

Consider also a world where personal aircraft were as easy to fly as driving a car. In partnership with this industry sector, known as general aviation, NASA is developing technologies that will make engines less expensive, training as easy as using your home computer, and flying your own airplane extremely safe.

Finally, creating radically new tools and work environments, in which engineers and designers develop their ideas and products, will be key in achieving all of our stretch goals. Accelerating the introduction of new technologies, as well as understanding their risks, costs, and benefits, will allow the U.S. aerospace industry to maintain its competitive edge.

A conceptual supersonic airliner design undergoes wind tunnel testing in NASA's 14- by 22-foot subsonic facility.

NASA research will enable a fleet of supersonic airplanes to someday provide affordable service around the globe at more than twice the speed of sound.

Pillar Three: Access to Space

In the coming decades, the space frontier will continue to expand as a busy intersection of U.S.-led international science, research, commerce, and exploration. Today, the cost of space access is roughly $10,000 per pound of payload delivered to low-Earth orbit. The growth of an otherwise dynamic, creative, and productive U.S. space commerce market is adversely affected by this daunting price tag.

The space industry can benefit significantly from the transfer of aviation technologies and flight operations to launch vehicles. High reliability and rapid turnaround are the first steps to increased confidence in delivering payloads on time with fewer ground crew. To make these ideas a reality, NASA and our industry partners are investing in an aggressive technology development effort. The linchpin of this effort is the X-33 technology demonstration vehicle.

This vehicle, already defined by customer needs, is developing promising advanced technologies, which, when demonstrated, can be quickly transferred to commercial use. NASA has incorporated a commercial focus from early technology planning through program implementation and evaluation. During this past year, the Lockheed Martin-NASA team has made tremendous strides in the X-33 program in preparation for its first flight in July 1999.

America can, and must achieve radical reductions in the cost of access to space–and do it in years, not decades. We must achieve this reduction without sacrificing safety and reliability. When successful, we will open the doors wider to space commerce, enable exploration-class missions, and protect our national security. From communications satellites to in-space manufacturing of revolutionary pharmaceuticals and electronics, we will reap untold benefits from this new frontier.

The full-scale liquid oxygen tank for the X-33 flight vehicle arrives at the Lockheed Martin assembly plant.

In 1999, the X-33 technology demonstration flight vehicle will begin its flight test program over the western United States, flying at up to 15 times the speed of sound.

The Three Pillars represent the technical challenges for addressing the broad range of national needs in aviation and space transportation. Meeting these challenges will create a transportation system that enhances mobility for everyone and protects the environment, as well as mobilize us into space. The connection between transportation and the U.S. economy is closely linked and significant.

In 1960, the Gross Domestic Product was $515 billion, and 35 years later, it had increased 14-fold to $7.2 trillion. In that same time, U.S. exports went up almost 30-fold, from $19.6 billion to $584.7 billion. This would not have been possible without consistent, reliable air transportation and communication.

Air transportation is essential to the economic success of America. Without it, we could not be competitive in the expanding global marketplace. Air transportation makes it possible to quickly move millions of people and goods worth billions of dollars to markets around the world. There are no practical alternatives. It has come to touch many parts of our lives–from business meetings to family visits and from delivering mail to delivering fresh produce.

The next major expansion of our transportation system will be into the realm of space. The space industry has already become one of the largest industries in the world. In 1997, total global revenues were nearly $77 billion, and, for the first time ever, commercial revenues exceeded those of Government expenditures.

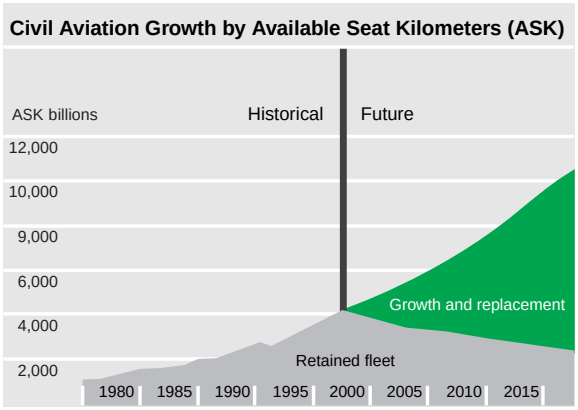
The space industry is more than just building and launching satellites and spacecraft. It includes the use and operation of these space vehicles, the management of the facilities on Earth that handle the satellites and process their data, and the commercial application of space technologies and services to other industries.

Growth Potential Is Impressive

The growing demand for air transportation is linked to the expansion of the world's economies, and to increased globalization and trade. The FAA forecasts that air travel will be nearly double today's volume in just 12 years. This is a staggering number when you consider that about 600 million people boarded commercial flights in 1997.

At the end of 1997, there were 12,300 commercial transports in the world fleet. This number is expected to grow to 17,700 in 2007, and to more than 26,000 by 2017. The measure of this growth, in terms of air travel capacity, is by available seat kilometers, or the number of seats in an airplane combined with the number of kilometers it is scheduled to travel in a year. There has been a rapidly expanding business in express air freight as well. Only 3 years ago, it represented 5 percent of international cargo traffic. Today, it is growing at a rate of 18 percent per year and is expected to account for 40 percent of the international cargo traffic by 2017.

The aerospace industry is also a direct major contributor to our Nation's economy. Aviation products are exported more than any other manufactured products, and are the highest positive contributor to the U.S. balance-of-trade. The forecasted world fleet growth represents approximately $520 billion in sales through 2007 and $1.25 trillion (1997 dollars) through 2017. The U.S. industries are competing for a significant share of this market.



Source: Boeing Current Market Outlook, 1998

Regarding the space industry, Standard & Poor's Industry Survey states that: "All analysts agree that the [commercial space] sector has been growing by at least 20 percent annually for several years." Fueled by non-Government applications, industry revenues are expected to reach $102 billion in the year 2000, representing an incredible 48-percent compounded growth rate. Firms involved in manufacturing satellite components are operating at near full capacity, with backlogs measured in billions of dollars. Worldwide employment in the space industry exceeds 900,000 people and is projected to grow by 70,000 workers each year to support this business forecast.

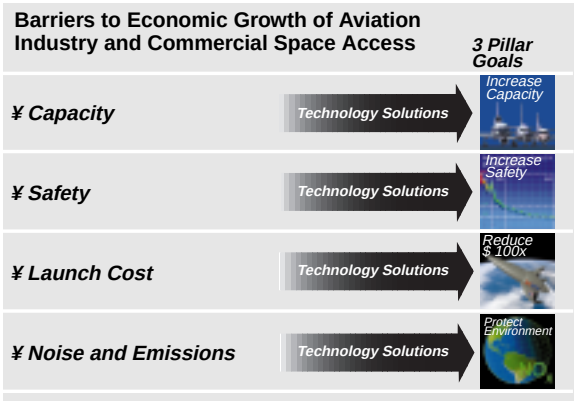
The space industry is changing dramatically. As it moves away from Government-driven needs toward market-driven growth, the industry will increase its vital role in the economies of many nations.

Thus, within these healthy forecasts for aviation and the future use of space lie our challenges.

Barriers to Growth

To ultimately benefit from the projected growth in aviation, we must be mindful of the potential barriers that could stifle that growth. As a Nation, we are already sensitive to these potential barriers. We are committed to the safety of the traveling public, the protection of the environment, a worldwide aviation system that can handle increased traffic demands, and a transportation system accessible to all.

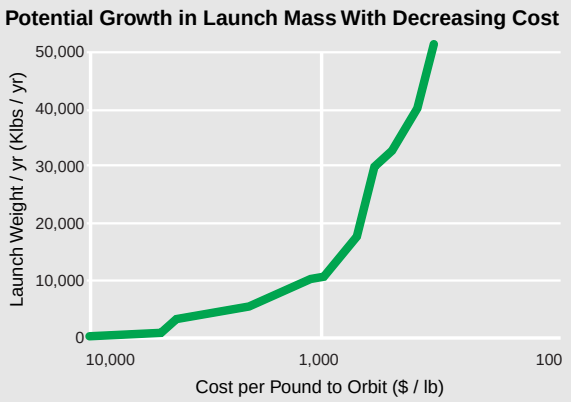
The FAA and industry have done an exceptional job in maintaining very low accident rates despite the increase in flights over the years. However, if we are to attain the projected doubling and tripling of air travel and its economic benefits, accidents must be cut back much further. In the area of the environment, the impact of increased traffic on airport noise and the atmosphere must be investigated and minimized. The Administration has focused on a global effort of reducing greenhouse gases and protecting the ozone layer. And though aviation plays a relatively small role in emissions, aircraft that are both cleaner and quieter will be necessary if an additional 5,400 transport airplanes are going to be flying in 10 years.



The airspace system will also be challenged by this growth. Specifically, in its 12-year forecast period, the FAA expects U.S. control tower operations to exceed 75 million, up from the 1997 level of about 63 million. If the national and international airspace systems are to continue to function effectively, we must find ways to ensure that future systems can handle the demand.

The growth anticipated for the space industry will also be limited unless progress is made in the key areas of reducing launch vehicle costs and improving their operability. Launch vehicles represent as much as 40 percent of the total project cost to satellite manufacturers and their clients. It has also been 25 years since we have developed a major new launch vehicle or rocket engine.

Today, access to orbit costs up to $10,000 for each pound of payload. This enormous expense is a growing obstacle to mission frequency, and limits achievements in commercial development, space science, and exploration. U.S. launchers, which were preeminent until the 1970's, now carry only about 30 percent of the worldwide commercial launch market. Without taking aggressive action, the Nation's launch industry will erode even further, losing a greater market share and high-value jobs.



Source: Commercial Space Transportation Study, May 1994

Research and Technology Investments

In 1996, $193 billion was invested in the United States on research and development. According to the National Science Foundation, 63 percent ($121 billion) of that investment was made by U.S. industry. Federal funding constituted 33 percent, while universities and nonprofit institutions funded the balance.

Historically, both industry and Government have partnered in the high-risk endeavors of aviation and space. While the outlook is very positive over the next 10 to 20 years, new technologies are required to support this growth. It is safe to assume that, even as technology solutions are found, more challenges will evolve along the way.

Over the past few years, the Administration and Congress have focused on balancing the Federal budget in the near term to assure the long-term economic health of our Nation. The past performance of the aerospace industry and its impact on our Nation, socially, politically, and economically, form a compelling argument for continued investment in this research. Today's investment in NASA, supporting the research outlined in the Three Pillars and Ten Goals, is a commitment to that future. If history is an indicator, this investment will be returned many-fold.

Structured for Progress

This Enterprise plays a unique role in delivering aerospace technologies. Our research objectives are defined by the Nation's critical needs and our customers' expectations, which we have codified in the Three Pillars and the Ten Goals. This has set our agenda for action to deliver enabling technology solutions. Our research is critical, but cannot stand alone. We must rely on our partners for implementing those technologies and delivering products.

Together with the FAA, U.S. industry, the Department of Defense, and the university community, we strive to deliver the research, technologies, and unique products and services that will add value to people's lives.

The Enterprise consists of five NASA Centers. The Ames Research Center, Dryden Flight Research Center, Langley Research Center, Lewis Research Center, and Marshall Space Flight Center all have unique roles. Each Center has built distinct competencies, or "Centers of Excellence," to spur technology and leading-edge research. By attracting world-class engineers and scientists and constructing many one-of-a-kind research facilities, the Centers are uniquely positioned to serve the Nation. Taken as a whole, the Enterprise serves as the center of science and technology for air and space transportation.

The Enterprise also has Agencywide responsibility for technology transfer and commercialization. This responsibility is to increase awareness in nonaerospace industries of NASA-developed technologies and to proactively assist the transfer of our technological knowledge into diverse applications. Through this process, the Enterprise helps ensure that the Nation's investment in technology provides social and economic benefits to all segments of society.

Ultimately, the beneficiaries of the Enterprise's investments are the public, U.S. business, and the military. The technologies developed by this Enterprise, and integrated into our aircraft and transportation systems by industry and the FAA, will help position the United States for continued leadership in aviation and space in the next century.

Three Pillars
Ten Goals

Critical National Needs

- *Safety*
- *Emissions*
- *Noise*
- *Capacity*
- *Affordable Air Travel*
- *High-Speed Travel*
- *General Aviation*
- *Design Tools*
- *Low-Cost Space Access*
- *In-Space Transportation*

Ames

Information Technology

Aviation Operations Systems

Working with Partners

ia

The Aeronautics and Space Transportation Technology Enterprise plays a unique role in delivering aerospace technologies. Providing world-class people and facilities, it is a catalyst for innovation.

Enabling Technology Solutions

ASTT Centers of Excellence and Mission Areas

Dryden

Atmospheric Flight Operations

Flight Research

Langley

Structures & Materials

Airframe Systems & Atmospheric Science

Lewis

Turbomachinery

Aeropropulsion

Marshall

Space Propulsion

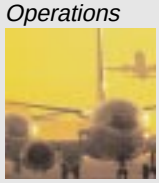
Transportation System Development

Benefits

Safe Travel

Protecting the Environment

Efficient Operations



Low-Cost Space Access

Technology Transfer

Beneficiaries

Public

Business

Department of Defense

FAA

NASA

Diagram showing NASA's role in creating value for customers and stakeholders.

Aeronautics and Space Transportation Technology Enterprise

The Enterprise is an investment in America's future.

The future we see includes:

- *A safer, cleaner world, in which the safety of air transportation is unquestioned and aircraft noise and emissions are dramatically reduced*
- *A more open world, in which people everywhere can quickly, easily and inexpensively travel wherever their lives lead them*
- *An expanded world, in which space is finally opened for all human endeavor*
- *A world of opportunity, in which technologies developed through NASA's R&D investment are fully exploited for the benefit of our society*

The Executive Board of the Enterprise manages the physical and intellectual capital that is at the heart of this Enterprise, as well as a portfolio of technology investments. The Board includes the Enterprise's Associate Administrator and the Center Directors. They are responsible for the strategies in developing technologies with the highest benefits, and aligning programs and partnerships to maximize NASA's contributions toward achieving the national goals.

The experimental, computational, and other critical facilities required to support research and technology programs and the expertise for resolving significant technical challenges are resources that have taken years to build. In an era of reduced Government spending, it has been essential to develop flexible alliances, partnerships, and networks to extend the capabilities of the Enterprise. The Board has the administrative challenge of sustaining cost-effective, world-class operations while continually improving upon "best practices" to ensure that we remain a robust research and technology organization.

The Enterprise has a proud heritage of excellence, innovation, and achievement, beginning in 1915 with the National Advisory Committee on Aeronautics (NACA). The exciting missions and technical challenges that are part of the Enterprise have created a spirit of dedication in our work force and a source of inspiration to new generations of scientists and engineers.

The accomplishments detailed in Part II of this report are representative of the wide range of research and technology needed to answer the technical challenges facing our Nation. With a steadfast commitment to research, dynamic partnerships, and a continued quest for leadership and innovation, the Enterprise will do its part in helping turn the goals into reality.

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* Retired in August 1998; as of press time, a successor has not been named.